Self-organized layer formation in a solidified magma ocean

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At an early stage of the Earth's and other planets' thermal evolution, the energy due to accretion or possibly due to subsequent giant impacts should have been sufficient to cause substantial melting of the mantle, creating a magma ocean (MO) [*Solomatov* (2007)]. Solidification of a thermally well-mixed MO is expected to proceed from the bottom upward, because the solidus temperature increases with depth more rapidly than the adiabat. During crystallization of the MO, the residual fluid is progressively enriched in iron and incompatible elements, resulting in a gravitationally unstable density stratification [e.g. *Elkins-Tanton et al.* (2005)].

After solidification of the MO, cooling of the planets is largely controlled by convective processes. These do not necessarily lead to a homogenization of the planet's interior, but can be self-organized into chemically distinct reservoirs. We perform numerical modeling of thermochemical convection in a 2D Cartesian geometry to investigate the self-organized formation of convecting layers in an initially unstably stratified fluid that is heated from below and cooled from above. Different initial mantle temperatures as well as a temperature-dependent rheology are taken into account.

We show that after an initial overturn, compositionally distinct layers evolve that exist over geologically relevant timescales. Formation and breakage of layers substantially influence the surface heat flow. Breakage of a layer, for example, leads to a jump in the heat flow. Different initial mantle temperatures affect the onset of convection at the surface which could be interpreted as the onset of plate tectonics. In an initially cold mantle, the onset of plate tectonics occurs later than in a mantle that is moderately heated or hot.

If a temperature-dependent rheology is applied, the unstable stratigraphy is not completely inversed during the overturn. Due to the high viscosity of the surface layer, the late-stage crystallized materials with the highest intrinsic densities remain at the surface. This may have a strong impact on the heat budget and convective style of the planet, as heat-producing elements are not only enriched at the core-mantle boundary but as well at the surface.

References

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